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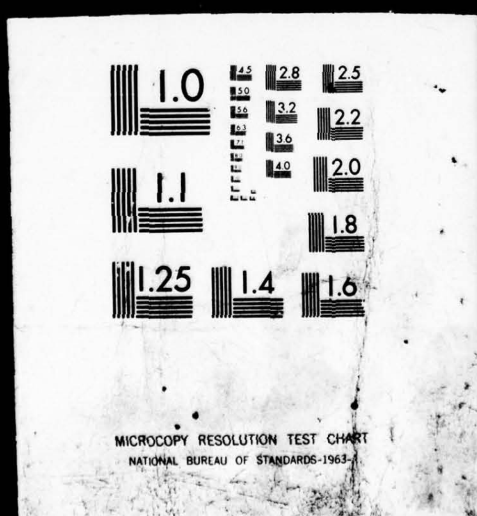

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EVALUATION OF THE ENGINEERING CHANGE
PROPOSAL COST EVALUATION MODEL

John W. Kehres, Captain, USAF
E. Dan Kolpin, Captain, USAF

LSSR 21-79A

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This thesis effort was directed toward the evaluation of a computer model designed as a tool for assessing cost impacts of aircraft engineering change proposals. The Engineering Change Proposal (ECP) Cost Evaluation Model was evaluated in a comparative analysis against the Air Force Logistic Command Logistics Support Cost (LSC) Model. Both models were exercised using data for a hypothetical aeronautical weapon system. The first run of the data served to establish a baseline configuration to which simulated ECPs could be compared against. Subsequent runs were made with changes to the baseline and cost estimates recorded. Cost estimates of the baseline configuration were compared to cost estimates of the changed configuration. Comparisons were made of the percent of change within each model and the total cost prediction between the two models.

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EVALUATION OF THE ENGINEERING CHANGE PROPOSAL COST EVALUATION MODEL

A Thesis

Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
Air University

In Partial Fulfillment of the Requirements for the
Degree of Master of Science in Logistics Management

By

John W. Kehres, BGS
Captain, USAF

E. Dan Kolpin, BS
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June 1979

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This thesis, written by

Captain John W. Kehres

and

Captain E. Dan Kolpin

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degrees of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT
(Captain John W. Kehres)

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT
(INTERNATIONAL LOGISTICS MAJOR)
(Captain E. Dan Kolpin)

DATE: 13 June 1979

Joel B. Knowles

COMMITTEE CHAIRMAN

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CHAPTER I

INTRODUCTION

An Engineering Change Proposal (ECP) is a formal proposal to alter the physical or functional characteristic of a system or item after the baseline configuration has been established (30:42). In major weapon systems acquisition the establishment of a baseline configuration is accomplished by the Physical Configuration Audit (PCA) during the Production Phase (15:2-7).

The Department of Defense (DOD) recognized that ECPs not only increase the cost of acquisition, but also impact Operating and Support (O&S) costs (26:1-5). Department of Defense Directive (DODD) 5000.28 established the requirement to analyze life cycle cost of ECPs where life cycle cost (LCC) is concerned with cost impacts over the entire life of a weapon system. The objective of the analysis was to provide estimates of life cycle cost differences and assess the cost implications of proposed changes so that the decision to accept or reject the Engineering Change Proposal can be made with the awareness of life cycle cost implications (15:4-32). However, the Government Accounting Office (GAO), in an audit of four major weapon systems, found that the management reviews

of ECPs did not assess the LCC impact of implementing or not implementing the ECPs. The lack of specific procedures was identified as the primary reason for not complying with the LCC analysis requirement (25:50). The audit revealed the need for a tool for assessing LCC impacts of accepting or rejecting an ECP.

The Air Force Acquisition Logistics Division has developed an ECP Cost Evaluation Model for evaluating ECPs during the production phase of major weapon system acquisition. The ECP Cost Evaluation Model is in an interim state, requiring evaluation and validation to develop the model into a versatile tool (6:iii).

Background

Engineering Change Proposal

ECPs have been categorized into two types: Class I and Class II. ECPs are classified as Class I, according to MIL-STD-480 (30:2-3), when one or more of the following factors are affected:

1. Functional configuration identification.
2. Product configuration identification.
3. Technical requirements (maintainability, reliability, weight, performance, etc.) which are below product identification.
4. Non-technical contractual provisions (cost, schedules, guarantees, etc.).

5. Other factors such as safety, compatibility with test equipment, interchangeability, suitability or replaceability.

Class II ECPs are documentary only (e.g., correction of errors or additions of clarifying notes) or a change in hardware which does not affect factors listed in Class I ECPs (e.g., material substitution) (30:2-3).

Class I ECPs are also assigned a priority (emergency, urgent, or routine) which determines ECP review and evaluation time requirements. Emergency priority has been assigned to ECPs that affect changes in operational characteristics which may seriously compromise the national security or hazardous conditions which may result in fatal injury or extensive damage of equipment (30:5). Time constraint for evaluation, decision, and contractual authorization of emergency ECPs is twenty-four hours (30:9).

Urgent ECPs effect a change in operational characteristics which may seriously compromise mission effectiveness, correct hazardous conditions which could result in injury or equipment damage, significant contractual requirements, or effect an interface which may cause schedule slippage or increased cost (30:5). Time constraint for urgent ECPs is fifteen days (30:9).

Routine priority is assigned to ECPs that do not fall into the Emergency and Urgent categories (30:5). Time constraint for evaluation is forty-five days (30:9).

Cost/savings factors associated with each ECP have been summarized according to MIL-STD-480 (30:18) in the following areas:

a. Production Cost/Savings
   1. Configuration item
   2. Factory test equipment
   3. Special factor tooling
   4. Scrap
   5. Engineering data revision
   6. Revision of test procedures
   7. Qualification of new item

b. Retrofit Costs
   1. Engineering data revisions
   2. Prototype testing
   3. Kit proof testing
   4. Retrofit kit
   5. Preparation of retrofit instructions
   6. Special tooling for retrofit
   7. Contractor field service engineering
   8. Testing after retrofit
   9. Modification of Government Furnished Equipment (GFE)
   10. Qualification of modified GFE

c. Integrated Logistic Support Cost/Savings
   1. Spares/repair part modification
   2. New spares/repair parts
   3. Retrofit kit for spares
   4. Operator training courses
   5. Maintenance training courses
   6. Revision of technical manuals
   7. New technical manuals
   8. Interim support
   9. Maintenance manpower

d. Other Cost/Savings

Prior to 1970 cost/savings factors associated with the above areas were aimed at the acquisition of the ECP with little regard to the effect on life cycle costs (15:1-5).

Life Cycle Cost

There has been considerable concern within the Department of Defense over the high cost of defense systems and the rapidly increasing cost of supporting systems after they are placed into operation (18). This concern has manifested itself in the application of life cycle cost (LCC) programs. The LCC of a major system is the total cost to the government of acquisition and ownership of the weapon system over its full life. It includes the cost of development, acquisition, operation, support, and where applicable, disposal (28:1).

It is important to recognize that while the decisions on selecting, improving, and utilizing candidate weapon systems may occur at different times, there is an important relationship between those decisions made early in the weapon's life and subsequent cost incurred by the weapon in the later stages (19:5). An analysis of total major weapon system costs revealed that only 40 percent of the total dollars expended can be traced to research, development, and acquisition costs, while 60 percent is consumed by operations and support (23). This analysis of weapon system costs is depicted in Figure 1. It has also been observed that of the decisions which drive or influence costs of ownership, about 70 percent are made in the early system stages (19:5).

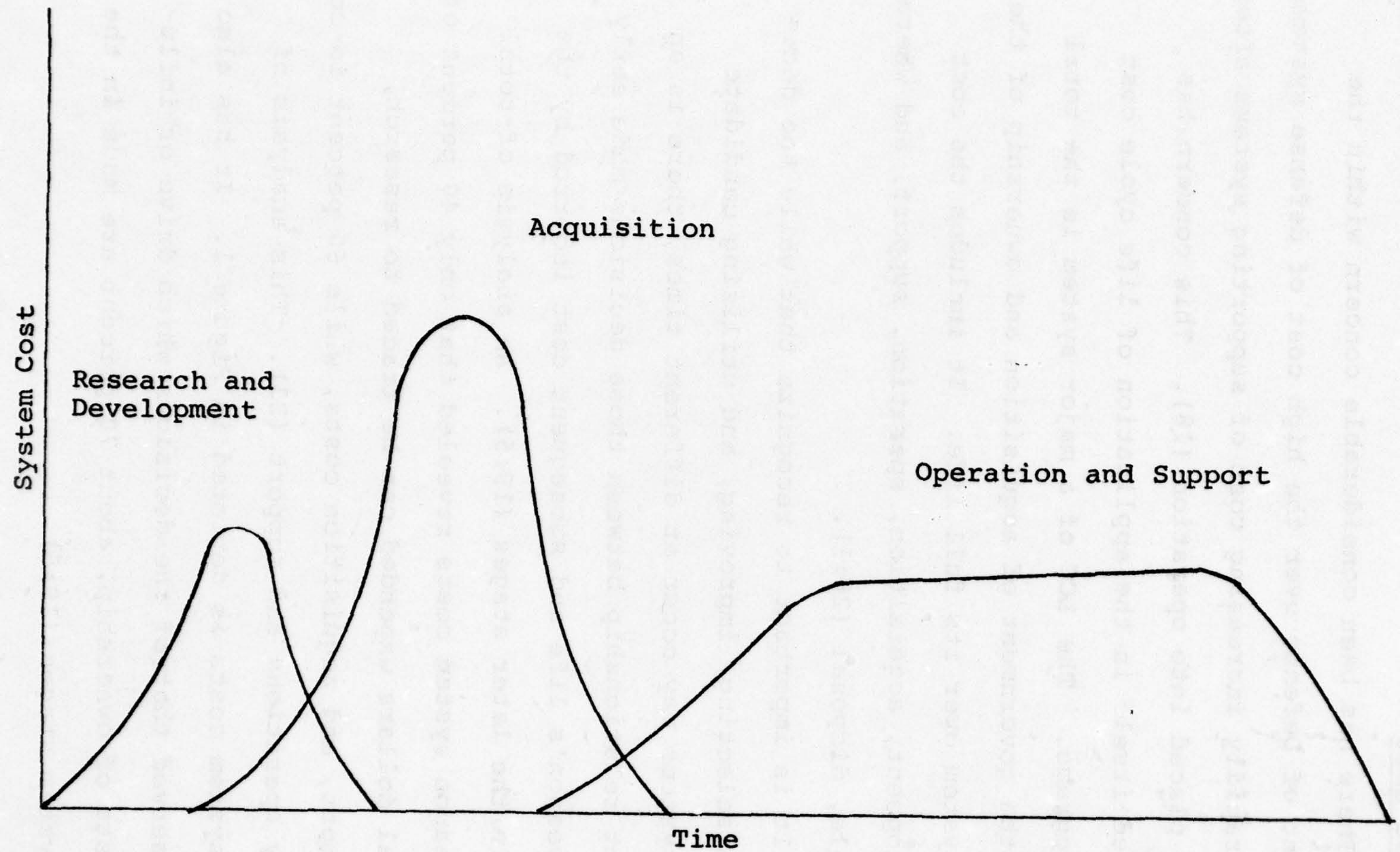

Fig. 1. Weapon System Life Cycle Cost (15:5-22)

The main objective in evaluating ECPs by life cycle cost analysis is to consider operation and support cost, as well as development and acquisition cost, in order to provide visibility of total economic consequences of approving (or disapproving) an ECP (15:1-4).

ECPs have been a significant factor in increasing major weapon systems acquisition costs. This is categorized as weapon system cost growth by the Air Force. Cost growth is the increase in constant dollar cost over the initial acquisition estimate (12:9). A 1977 audit by the Government Accounting Office of thirteen selected Air Force major systems acquisitions revealed that ECPs generated 3.5 billion dollars in cost growth, or approximately 25 percent of the total cost growth (32:4).

However, cost growth resulting from the implementation of an ECP may be acceptable and sometimes desirable in order to reduce the weapon system life cycle cost (29:2-3). Figure 2 graphically illustrates this concept of acceptable cost growth. Alternative A represents the approval of the ECP and alternative B represents the disapproval of the ECP. Alternative A increases the acquisition cost of the weapon system and therefore results in cost growth. However, the cost growth is outweighted by the reduction in operating and support costs which yields a life cycle cost that is lower than alternative B (29:2-3).

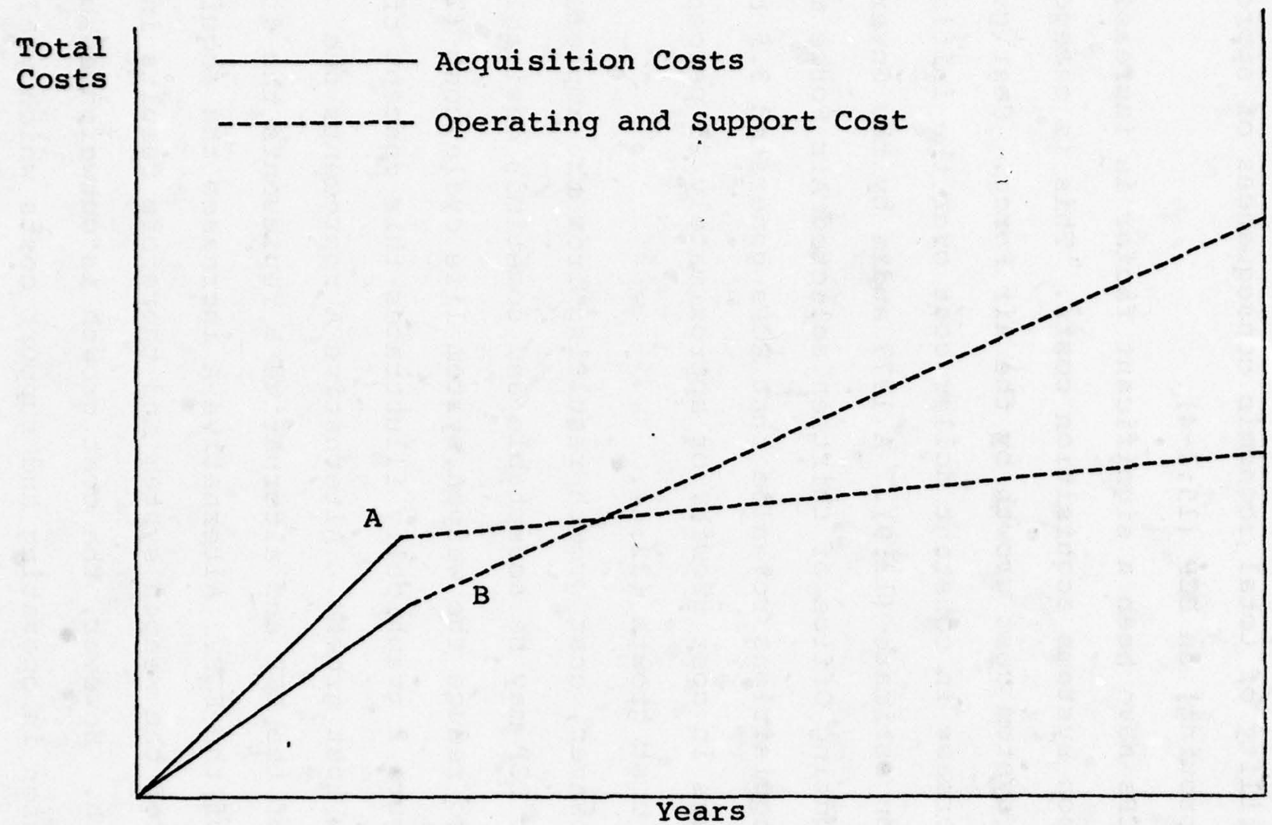

Fig. 2. Total Costs over Time (29:p.2-3)

In summary, the life cycle cost program is designed to bring about reduction in system and equipment operating and support costs, primarily through early consideration and analysis of operating and support implications of design alternatives. An important way to achieve these cost reductions is through more extensive and effective use of life cycle cost models (14:1).

Life Cycle Cost Models

Research revealed that there are numerous models available for addressing decision issues that effect life cycle cost. The Joint Air Force System Command (AFSC)/ Air Force Logistics Command (AFLC) Commander's Working Group on Life Cycle Cost has defined ten categories of models based on the intended application of each model (14:7-8). These ten categories are:

1. Cost Factor Model--A model in which each cost element is estimated by multiplying a key weapon system parameter by a factor which is derived as a function of Air Force cost experience on similar weapon systems.
2. Accounting Model--A set of equations which are used to aggregate components of support costs, including costs of manpower and material, to a total or subtotal of life cycle costs.
3. Cost Estimating Relationship Model--A statistically derived set of equations each of which relates LCC or some portion thereof directly to parameters that describe the design, performance, operating, or logistics environment of a system.
4. Economic Analysis Model--A model characterized by consideration of the time value of money, specific program schedules and the question of investing money in the near future to reduce costs in the more distant future.

5. Logistic Support Cost Simulation Model--A model which uses computer simulation to determine the impact of an aircraft's flying program, basing concept, maintenance plan, and spare and support resource requirements on logistic support cost.

6. Reliability Improvement Cost Model--A set of equations that reflects the costs associated with various increments of improvement in equipment reliability.

7. Level of Repair Analysis Model--A model that, for a given piece of equipment, determines a minimum cost maintenance policy from among a set of policy options that typically include discard at failure, repair at base, and repair at depot.

8. Maintenance Manpower Planning Model--A model that evaluates the cost impact of alternative maintenance manpower requirements or the effects of alternative equipment designs on maintenance manpower requirements.

9. Inventory Management Model--A model that determines, for a given system, a set of spare part stock levels that is optimal in that it minimizes system spares costs or minimizes the Not Operationally Ready Supply (NORS) rate of the system.

10. Warranty Model--A model that assesses the relative costs of having the Government do in-house maintenance versus having this maintenance performed by contractors under warranty [14:7-8].

Accounting models have primarily been used by the Air Force with respect to design tradeoff decisions. Of the available accounting models, the Air Force Logistics Support Cost (LSC) Model has been used to compute the effects of ECPs on life cycle costs for the B-1, F-16, and A-10 aircraft programs (14:15-18). Since the LSC model was used for cost tradeoff studies on our recent major acquisitions, a brief explanation of the model is in order.

Logistics Support Cost Model

The AFLC Logistics Support Cost (LSC) model is an accounting model used to estimate the logistics support

cost over the expected life of a weapon system (14:15). The model contains eleven equations or submodels, each of which represents a major cost driver of total logistics support cost (14:16). The eleven components are:

1. Initial and replenishment line replaceable unit (LRU) spares cost
2. On-equipment maintenance cost
3. Off-equipment maintenance cost
4. Inventory entry and support management cost
5. Support equipment cost
6. Cost of personnel training and training equipment
7. Cost of management and technical data
8. Facilities cost
9. Fuel consumption cost
10. Cost of spare engines
11. Software support cost

The LSC model was intended for application in three different areas: (1) to obtain an estimate of the differential logistics support costs between the proposed design configuration of two or more contractors during source selection; (2) to establish a baseline for contractual commitments on certain aspects of operational supportability which will be subject to verification; (3) to use as a decision aid in discriminating between design alternatives during prototyping or full-scale development (14:15-16).

It was not originally intended to be used to compute the logistics support cost effects of ECPs (13); however, it has been used for the purpose of evaluating ECPs in the B-1, A-10, and F-16 aircraft programs (14:15-18), three of our most recent major acquisitions.

The Joint AFSC/AFLC Commanders Working Group on Life Cycle Cost found that the available life cycle cost models, including the LSC model, have five major deficiencies (14:8):

1. They are not sensitive to performance and design parameters.

2. They are too complex.

3. They require input data which frequently cannot be provided in a timely manner or with the desired level of confidence.

4. They are not sensitive to wear-induced failures.

5. They are not time sensitive.

The LSC model may be deficient in these five areas, yet the model is a widely used model for system acquisition. The model has been used in the source selection environment and within the design tradeoff environment (14:16).

Problem Statement

Current models available to cost analysis for ECP evaluation are deficient in relation to one or more of the deficiencies listed above. The systems cost analyst needs

a cost evaluation model that is sensitive to design and performance parameters yet is simple and easy to use. The model must also be capable of investigating time sensitive costs accruable to changing systems inventory and changing failure rates resulting from burn-in and wear. The model should use easily attainable input data and be capable of evaluating questionable data elements across a confidence band established by the user.

The ECP Cost Evaluation Model appears to fulfill cost analysts' needs for a tool they can use with confidence. The literature on the model states that it is time sensitive and less complex than models currently in use by the USAF. However, an evaluation of the model is required in order to determine its usefulness as a cost estimating tool.

Literature Review

Models

Models are representations of a real system and have three distinct advantages (1:60). The first advantage arises from the model's ability to provide the user with an understanding and knowledge of the real system (10:49). Second, models are less complex than the real system but still able to predict and explain phenomena with a high degree of accuracy (1:60). Third, models can be controlled and manipulated easier than the real system (1:60).

Types of Models

Three types of models were found in review of modeling literature: iconic, analogue, and symbolic (1:60). In iconic models the relevant properties of the real system are represented by the properties themself, usually with a change in scale. Some examples of iconic models are photographs, maps, and model airplanes. "Iconic models are generally specific, concrete, and difficult to manipulate for experimental purposes [1:60]."

Analogue models use one set of properties to represent another set of properties (1:60). An example of an analogue model is the use of a hydraulic system as an analogue of electric, traffic, or economic systems. "In general, analogue models are less specific, less concrete, but easier to manipulate than iconic models [1:60]."

Symbolic models use letters, numbers, and other types of symbols to represent system variables and the relationship between the variables. Symbolic models take the form of mathematical relationships that reflect the structure of the system being modeled. Symbolic models are most general, most abstract, easiest to manipulate experimentally, and usually yield more accurate results under manipulation than iconic or analogue models (1:61).

Model Characteristics

Three model characteristics are defined. These are static or dynamic, steady-state or transient, or open or closed characteristics. A static model describes a relationship that does not vary with time; a dynamic model deals with time-varying interactions (10:50).

Models can be further characterized according to whether their behavior is primarily steady-state or transient. A steady-state model is a model that is repetitive with time and in which the behavior in one period is the same as any other period (10:51). A transient model on the other hand describes changes to the system that occur over time. Transient responses are one-time occurrences such as new plant construction and marketing development (10:51).

In addition, models may also be classified as open or closed. An open model is a model that receives externally supplied variables. The distinction is not as clear as indicated since different degrees of "openness" can exist (10:51). A closed model, therefore, functions without external variables. A closed model generates the values of variables internally through time by the interaction of the variables. Information-feedback systems are basically closed systems (10:51-52).

Model Evaluation

AFALD model evaluation methods, as well as the other sources, emphasize the requirement to evaluate models in the environment for which the model was designed. A model may be excellent for one specific purpose but misleading and useless for another (17:16). AFALD evaluates models based on validity, completeness, sensitivity, availability of input data, and model documentation (21:8.16-8.17).

AFALD defines validity as a measure of how well the model represents the real-world system under study (17:16). Validity and verification have been used interchangeably by model developers. The Institute of Management Science (TIMS) has distinguished between validity and verification by defining verification as determining whether the model performs as intended (24:2). AFALD considers validity as encompassing the TIMS definition of verification, and validity has been treated as such in the thesis (13).

Completeness is whether the model contains the appropriate elements. If the decision issue under consideration affects some but not all elements, only the affected elements may need to be considered (17:16).

Just as the system being modeled is sensitive to changes, the model must also represent this sensitivity in order to be useful as a decision tool (17:17).

Analyzing the availability of input data is a most important and vital step for without data the model will be useless. It must be feasible to obtain accurate input data which is in the form required by the model or capable of being transformed without loss of accuracy (17:17). Model data problems in the Air Force have been discussed earlier.

Model documentation in the Air Force is normally in the form of a user's guide. This guide must provide for quick review, easy understanding, clear determination of application, implementation of the model, and analysis of the results (17:17-19).

AFALD has also evaluated new models with existing models (13). New models may have been developed to improve the validity, completeness, sensitivity, or other model criteria as well as add other model enhancements.

Model evaluation methods employed by Harvey Wagner in his book The Principles of Operations Research are based on five interrelated characteristics of completeness, domain of application, convergence properties, computational requirements, and sensitivity (33:99-100). Wagner not only defines completeness as containing the appropriate elements for the decision issue under consideration but also includes examining the correctness of the algorithm rules (33:99).

The second characteristic, domain of application, stresses the importance of applying a model only in the environment for which the model was designed and not attempting to force a problem or decision issue to fit the model (33:99-100).

The third characteristic, convergence properties of a model, applies mainly to linear programming models where the goal is to maximize or minimize the value of the objective function within certain constraints (33:99-100). The convergence property relates to the number of iterations required to obtain the problem solution (33:100).

Sensitivity, the last characteristic, examines how much numerical accuracy is required to ensure the model operates satisfactorily as well as examining whether a small change in the value results in a different solution (33:100).

Forrester judges models based on purpose, predictive capability, model structure and detail, and nonquantitative assessments (10:115-129). The purpose of a model relates to the specific objectives of the model and the system the model is representing (10:115-116).

The predicting capability, which is interrelated to the model's purpose, is its ability to predict the effects of changes in the actual system (10:116).

Model structure and detail are examined relative to system's boundaries, interacting variables, and values of

the parameters (10:117-119). The system's boundaries limit the application of the model to the system being modeled (10:117). If boundaries range unnecessarily far, the model will be distracting and may lead to confusion (10:117). The system's boundaries also limit the variables and the interaction of the variables.

The model must contain an effective choice of variables with proper variable interaction (10:118). The lack of proper system variables and variable interaction will destroy the utility of the model as a decision tool (10:118).

Parameter values are the constant coefficients used in the model. The values can normally be derived from actual data through statistical tests (10:119).

Nonquantitative assessment of a model may be required if the elements of the model are drawn from non-numerical sources in the form of individual personal knowledge and verbal and written descriptions (10:128). All elements should have a conceptual meaning that can be individually considered with respect to the actual system. The elements can then be examined, argued, and checked against past incidents and experiences (10:128-129).

<u>Data Sources</u>

One of the most important steps in model construction is to analyze the data base. No amount of statistical

analysis can compensate for gross inadequacies in a data base (9:130). Cost analysts in the military typically devote a considerable amount of time to collecting data, to making adjustments in data to ensure consistency and comparability, and to providing for proper storage of information so that it may be retrieved rapidly when needed (9:130).

There have been numerous studies concerning data problems in the Air Force; however, this literature will treat only those problems summarized in a Rand Corporation study (9). The study concluded that many existing data sources are deficient in one or more of the following ways:

1. Information may be in the wrong format.

2. Various irregularities, inconsistencies, and noncomparability may be present.

3. Gaps in information may exist at various critical paths.

4. Only a small number of relevant cases for the historical record may be available in the "small sample" problem (9:133-165).

Historical data from prior acquisitions and their in-service performance are frequently used in arriving at cost estimates for new or proposed systems.

Cost Estimating

In general, there are three basic approaches to cost estimating: analogous systems, industrial engineering and parametric. All three are frequently used in the preparation of cost estimates during the acquisition process (4:19).

The analogous system approach is a direct comparison of a new system to a similar system with known costs. For example, the landing gear system for a new fighter aircraft may be quite similar to the landing gear system on an aircraft in service. The cost data existing on the in-service system after being adjusted for inflation may produce a general cost estimate for the new landing gear system.

The analogous method

> . . . when it is applied in a carefully planned, detailed, and conscientious manner, is perhaps the most powerful method of estimating. The greatest advantage derived from this method is that it can be made quickly without the time and cost otherwise required to develop an in-depth analysis. Unfortunately, the analogous system frequently receives a skeptical reception [4:19].

The analogous system approach to cost estimating becomes guesswork when applied to state of the art systems. In comparing cost of existing systems to estimate the cost of a new system, the level of technology and its associated cost are not accounted for (4:20).

The industrial engineering approach to cost estimating can be used when the item design is well known and well established (4:20). This approach is to identify specific cost elements like training, manpower, material, etc., accumulate the cost for each element, and aggregate costs to provide a total system cost. The industrial engineering method:

> . . . has definite limitations early in the weapon system development cycle because of procedural difficulties in handling "unknowns." However, the industrial engineering method represents the most precise approach to estimating, and it is the basis for most production contracts [4:22].

The parametric approach to cost estimating is similar to the analogous method in that prior systems cost experiences are used to derive a cost estimate for a new system. Specifications, performance, and cost data are collected on prior acquisitions then analyzed for statistical trends to relate two or more variables. Through curve fitting techniques, systems' costs may be estimated in relation to known parameters of the new system such as size, weight, performance, etc. (15:5-6). The relationships developed by this method are called cost estimating relationships (CER).

> The parametric estimating approach is required by DOD Memorandum for all cost estimates presented to the Defense Systems Acquisition Review Council (DSARC). Basically, this approach permits a blending of known changes in system acquisition management and technology with the uncertainties of system design during the early development phases of the acquisition process. The

parametric estimate (periodically updated by known changes in management, technology, and data) can be used as a check on the more definitive industrial engineering cost estimate [4:23-24].

Project ABLE

Acquisition Based on consideration of Logistics Effects (ABLE) was initiated by the Operation Analysis Office of AFLC in mid 1968 with the primary emphasis on "design for support" and design "trade-offs" (8:2). Project ABLE, as it was named, produced a series of mathematical formulae which subsequently became known as the "A-X 10-year Operating and Support (O&S) Cost Model." The model was intended to be used in the source selection of the A-X close support aircraft and the determination of a contractor-incentive award fee. The model eventually became known as the AFLC O&S Cost Model and will be referred to as the O&S model in the remainder of the thesis.

The O&S model was validated by Captain Raymond E. Cavender (USAF) in March 1971 (5). Captain Cavender's task was to gather the necessary and appropriate data from existing Air Force data information systems and exercise the O&S cost model as it was developed for use in the A-X weapon system acquisition (5:1). The F-4E aircraft wing stationed at George Air Force Base (AFB) was selected as the data source for exercising the model. The rationale for selecting George AFB was to eliminate contamination of data from different type, model, and series of aircraft.

At George AFB, there were F-4E aircraft and essentially no other aircraft types (5:1). Cavender's final report

> . . . records the results of exercising the model with input data drawn from existing Air Force data systems and reflecting F-4E experience. The feasibility of the F-4E exercise contributed to confidence in the practicality of using this model for credible estimation of weapon system Life Cycle Costs, and in turn for using these costs in the multitude of decisions that are faced when developing and producing a new hardware system (including Source Selection, Integrated Logistics Support tradeoffs, etc.) [5:ii].

With the validation of the O&S model completed, it was time to apply it.

<u>The A-X Application of the O&S Model</u>

The competing contractors for the A-X program were given the final revision of the O&S model in August 1971 (8:2). The competing contractors (Northrop and Fairchild) and the A-X System Program Office coordinated the costing methodology, agreed on basic assumptions, and jointly developed ground rules for calculating the various cost elements of the model (8:2). This joint effort resulted in incorporation of some contractor suggested changes to the model which changed the total number of cost elements from nine to thirteen (8:4). The thirteen elements are:

1. Line Replaceable Unit (LRU) spares
2. LRU off equipment maintenance
3. On equipment maintenance
4. Ineffective off equipment maintenance

5. New item inventory
6. Support equipment
7. Training Equipment
8. Technical data
9. Type 1 training
10. Fuel consumption
11. Spare engines - base pipeline
12. Engine maintenance - off equipment
13. Spare engines - depot pipeline

The A-X was the first major weapon system acquisition to which the USAF applied life cycle cost procurement techniques. The O&S cost model, which has its genesis in Project ABLE, played an important part in the source selection. The contract was awarded to the Fairchild Republic Company (FRC) for the production of the A-10 close air support aircraft. The model was continued in use after source selection for design trade-off studies and determination of a contractor incentive award fee (16). It was also used to establish a baseline configuration and cost evaluation of engineering changes.

> [S]everal major aircraft configuration changes were mandated. This included the addition of an auxiliary power unit, cockpit pressurization, leading edge slats and a new ejection seat. These were classified as "Baseline changes," and FRC was directed to calculate the impact of these changes and to submit this data susequent to contract award. This submission established the baseline weapon system configuration to which all subsequent engineering changes (ECP) were applied [8:7].

The O&S cost model was also used to evaluate ECPs but was not oriented toward assessing ECP cost impacts and therefore was not a good tool for ECP evaluation (2:2). In March 1978, a contract change proposal was submitted to the A-10 contractor which addressed the following model deficiencies in evaluating ECPs:

a. Some of the equations are not sufficiently explicit (e.g., Peculiar Support Equipment).

b. The equations do not accurately reflect present Air Force operations (e.g., spare safety levels, equipment usage).

c. Air Force supplied parameter values and constants are out of date and unrealistic when compared to current programmed flying hours, aircraft inventory and airframe life projections.

d. Contractor provided parameter values and constants are also unrealistic. A good example is MTBR. This will change to MTBF under the revision but the same applies. In future O&S analyses the contractor must use MTBF values for current configuration computations which are based on actual field experience as opposed to the predicted/mature value. The recommended computations should reflect the improved predicted MTBF of the changed design to show the real savings to be achieved.

e. In general the current model was designed for a measurement of total O&S costs versus predicted instead of an assessment of design alternative [2:2].

Objective

The objective of this study is to evaluate the ECP Cost Evaluation Model as a decision tool for measuring the life cycle cost impacts of implementing/rejecting an ECP.

Scope

This research effort is limited to evaluating the life cycle cost estimates generated by the ECP Cost

Evaluation Model in comparison with the cost estimates generated by the LSC model.

Research Question

How does the ECP model compare with the LSC model in terms of:

1. The percent of change in cost predictions between the baseline configuration which is established by the physical configuration audit (PCA) and represents estimated cost of not implementing an ECP and a changed baseline configuration representing estimated cost of implementing an ECP?

2. The total life cycle cost predictions of implementing an ECP?

CHAPTER II

THE ECP COST EVALUATION MODEL

Origin of the Model

The Engineering Change Proposal (ECP) Cost Evaluation Model was designed by the Concepts and Analysis Directorate of the Air Force Acquisition Logistics Division (AFALD) in September 1977. It is not an entirely new model but an outgrowth of a 1975 U.S. Army computer model for Aircraft Product Improvement (PIP) and Engineering Change Proposal Economic Analysis. The AFALD ECP model incorporated essentially the same basic logic and methodology as its parent Army model but was modified and expanded to meet Air Force requirements (6:13).

Features of the Model

The ECP model is a monthly processing-accounting model which has the distinct and favorable advantage of evaluating time sensitive elements inherent in weapon system acquisitions. This feature provides the capability of assessing costs accruable to the existing inventory as it exists in each month of its useful life (6:iii). To do this, inventory is adjusted monthly based on the production schedule for the remaining months of the production contract

minus those aircraft lost through attrition in the prior months (6:iii).

The time sensitive monthly processing feature of the model keeps track of modified and unmodified items/systems and the associated costs of maintaining both (6:iii). This allows the user to simulate the phasing-in of an ECP through a scheduled program or attrition, and assess the cost impact over the time interval of its incorporation into production aircraft and modification of on-hand systems (6:iii-v).

Another feature of the model is the conversational mode. Conversational mode meaning that the user interacts with the computer while the program is on line, and inputs are made directly from the terminal keyboard (6:1). The program prints questions or options to which the user responds. The output is then printed in the format selected by the user. This feature allows the user to evaluate many alternatives, to eliminate those alternatives which are not viable, and to rank preferred alternatives.

The model also has the advantage of permitting the user to select the demand activity generator which is applicable to the item being modified or changed by the ECP. The demand activity is that activity that generates maintenance actions and subsequent demands for an item. The demand activity generators available in the model include: flying hours, operating hours, sorties, landings, and

elapsed time (6:6). This choice of demand activity generators allows for the evaluation of proposals which are not necessarily sensitive to flying hours.

In addition, the ECP model has two optional features, a variable program option and a sensitivity study option. The variable program option allows the user to input factors (multipliers) for mean time between maintenance action[1] (MTBMA), flying hours, and attrition rates in order to investigate the effects of changes caused by time or situation (6:7). The MTBMA input factor can be used to simulate the effects of time where MTBMA improves as the system matures or deteriorates as a result of age and wear (6:7). The situational effect, where it is known that flying hours will be continually reduced over the lifetime of the system due to dwindling fuel resources or other operating costs, can also be evaluated by inputing factors into the variable program option (6:7).

The second option is a sensitivity study which allows the user to establish trends and quantitative relationships between variables (20:3). Three values (pessimistic, most likely, and optimistic) can be input directly

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[1]MTBMA is the average time that a particular unit will perform before maintenance action is required, and includes maintenance actions caused by failure of the unit, preventative maintenance, and false removals (6:C2-C3). False removals are the removal of a unit which was diagnosed as causing a discrepancy but was later verified as performing correctly.

for up to four different variables listed in Appendix C. The forty-five variables listed in Appendix C can be summarized as manhour, cost, and variable program factors. Summary outputs which depict the effects of the individual changes can be compared to analyze the sensitivity of the changed variables.

Input Factors

Four sets of factors are input into the model from the file in the sequence given below:

1. Those central factors which set limits to time spans like system life, set starting points like number of aircraft at start, and discriminate between processing sequences such as making the basis for item modification either attrition of the old item or a definite schedule.

2. Those variable program factors which provide values for some of the more important variables like MTBMA and repair cycle times.

3. Manhour factors to perform various maintenance actions.

4. The cost factors applied to materials, manhours, purchasing, and shipping costs of modification and retrofit kits (7).

Output Products

The model provides output products in three forms: monthly, yearly, and single summary line. Each of the three formats provided an option to reflect costs associated with three data sets: (1) the old item alternative, (2) the new item alternative, or (3) a composite (6:15). One other option of the computer program is that it controls the width of the printout. Wide carriage terminals may not be available to all potential model users. The combinatorial effect of two printout widths, three forms, and three data sets, give the user a choice of eighteen possible print formats (6:15-16).

CHAPTER III

METHODOLOGY

Introduction

The methodology used to evaluate the ECP Cost Evaluation Model was a comparison of its projected cost estimates with the cost estimates projected by the Air Force Logistics Command LSC model. In order to make this comparison, a compatible data source was required (compatible meaning that the data inputs into both models represent the same costs). To insure this compatibility, the AFALD data file for LSC model maintenance was used as the control data base from which all data elements could be applied directly or easily developed.

Hypothetical engineering change proposals were simulated by changing the data base to reflect a 100 percent increase in mean time between maintenance action for selected items for an investment of 30 percent increase in unit price (11). Each model was exercised providing life cycle cost estimates for the baseline configuration (not implementing the ECP) and the changed configuration as a result of implementing the ECP. A percent of change between not implementing and implementing the ECP was calculated and compared for each model as well as a comparison

of total projected life cycle costs between the models. No attempt was made by the researchers to quantify the differences in the comparisons; it was left to the potential user to select the model most appropriate to his particular situation. A similar methodology was applied by the A-10 Systems Program Office in the evaluation of Target Logistics Effects (TLEs) and Measured Logistics Effects (MLE) as well as the initial evaluation of ECP impacts on TLEs (10:2-4).

Data Source

The LSC test file maintained by the AFLD Concepts and Analysis Branch (XRS) contains realistic data for a hypothetical aeronautical weapon system (13). The file is used by XRS to debug the AFLC Logistics Support Cost (LSC) Model when changes are made to the computer model. This file was used by the researchers as a control data file. The control data file contains five levels of data for a hypothetical fleet of nine hundred aircraft (3:13-14). The five levels of data are:

1. Weapon system data
2. Propulsion system data
3. Subsystem data
4. First line unit (FLU) data
5. Support Equipment (SE) data

The AFALD/FILEDIT program is a batch program used to edit the LSC model files, link each numerical value with the name of the variable and make logic checks on the data (3:16). This edit program was linked with the control data file and exercised to generate a computer listing. It was this listing that provided the data from which variables required by the ECP model could be derived or directly transcribed (see Appendix A).

The LSC model was then exercised using the control data file and the output product was used to establish a baseline configuration for the hypothetical aircraft weapon system and its five subordinate major functional systems.

The five subordinate systems each have their own system level data and are identified by Work Unit Codes (WUC) prescribed by Military Specification MIL-M-38769A (3:1-1). A WUC is a code consisting of five alpha-numeric characters to identify the system, subsystem, or component against which maintenance actions are recorded (27:II-001). A system is identifiable by the first two digits of the WUC. The five systems and their WUCs addressed by the data files are:

System	WUC
Airframe	11000
Powerplant	23000
UHF Communications	63000

System	WUC
Radar Navigation	72000
Fire Control	74000

Each system is further broken down into first line units (FLU). A FLU is the first level of assembly below the system that is carried as a line item of supply at base level and is usually the highest level of assembly that is removed and replaced as a unit. A FLU is assigned a unique WUC against which maintenance actions are reported (3:1-1). The FLU level data for selected items were modified to investigate cost impacts of ECPs.

In addition to the control data file, two files were created in order to simulate engineering changes to two different FLUs. The first file was named TEST.1 and contained the same data elements as the control data file with the exception of data relevant to FLU Work Unit Code 72FBO (radar navigation unit).

This particular FLU was selected for experimentation because it had no support equipment associated with its maintenance. The changes made to the FLU data were in the unit price and mean time between failure (MTBF). These changes were made to simulate a 30 percent increase in unit price as an investment for a 100 percent increase in MTBF (11).

The second test file was named TEST.2 and contained the same modification of the control data file as TEST.1,

except that the modification was made to FLU Work Unit Code 23ABA (compressor fan assembly) data. This particular FLU requires four pieces of support equipment for field and depot level maintenance. It was selected for experimentation because of the support equipment cost drivers.

The LSC model computer program was twice exercised using the two test files. The products from these computer runs, combined with the control data, provided the researchers with a ten-year logistic support cost breakout of:

1. Total logistics support costs of the hypothetical weapon system at the time of the physical configuration audit.

2. Total logistics support costs as they were effected by an ECP applied to a FLU without support equipment.

3. Total logistics support costs as they were effected by an ECP applied to a FLU with significant support equipment cost drivers.

The ECP model was then exercised using the data from the control data file and the two test files. The control data file provided the data elements associated with the old item or item to be modified by the simulated ECP.

Eight runs of the ECP model were made in order to investigate the effects of field and depot level modifications and the effect of incorporating the change during

an intermediate stage of production. As previously stated, the ECP model is time sensitive and capable of portraying costs resulting from the phasing-in of an ECP and those costs associated with maintaining the old item until it is either removed from the inventory or modified to the new specification. For example, the control data represented a purchase of nine hundred aircraft. The ECP was arbitrarily approved for incorporation on the 491st and subsequent aircraft. The 490 aircraft already in the field and the initial spares purchased and on hand would require modification or removal from the inventory through attrition or schedule.

Two runs were made with production in progress for each FLU using the data from the two simulated ECPs. One run was with field level modifications and the other with depot level. The intent was to investigate the ECP model's capability of measuring cost trade-offs of depot labor rates against the elimination of second destination shipping charges.

Two additional runs were made for each FLU on the same data without production in progress, both depot and field level modifications were investigated. The eight different simulated ECPs were numbered ECP 1 through ECP 8 and are shown in Table 1.

TABLE 1

SIMULATED ECP IDENTIFICATION

ECP Number	WUC	Level of Compliance	Production Point
ECP 1	72FBO[a]	FIELD	900 ACFT ON HAND PRODUCTION COMPLETE
ECP 2	72FBO	DEPOT	900 ACFT ON HAND PRODUCTION COMPLETE
ECP 3	72FBO	FIELD	400 ACFT ON HAND 500 IN PRODUCTION
ECP 4	72FBO	FIELD	400 ACFT ON HAND 500 IN PRODUCTION
ECP 5	23ABA[b]	FIELD	900 ACFT ON HAND PRODUCTION COMPLETE
ECP 6	23ABA	DEPOT	900 ACFT ON HAND PRODUCTION COMPLETE
ECP 7	23ABA	FIELD	400 ACFT ON HAND 500 IN PRODUCTION
ECP 8	23ABA	DEPOT	400 ACFT ON HAND 500 IN PRODUCTION

[a]WUC 72FBO represents the radar navigation unit.

[b]WUC 23ABA represents the engine compressor fan assembly.

Comparison of the Models

Two approaches were taken in comparing output from the LSC and ECP models. The first approach was to compare the percent of change generated by each model. This was accomplished by comparing the LSC model output for the baseline configuration with the LSC model output for each simulated ECP. The percent of change was calculated for the simulated ECPs using the following formula:

$$C\% = 1 - \left(\frac{T_{c(2)} - V_c}{T_{c(1)} - V_c}\right) * 100$$

where,

$C\%$ = percent of change between baseline and ECP configuration cost,

$T_{c(1)}$ = total FLU cost for the baseline configuration,

$T_{c(2)}$ = total FLU cost for the ECP configuration, and

V_c = cost factors not included in the comparative model.[2]

The percentage of change was also computed for the ECP model using the above formula. The percent of change produced by each model was computed in order to provide the potential user with a measure of change between the estimated costs of the baseline configuration and that of the modified configuration generated by each model.

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[2]The cost factor addressed in the LSC model but not addressed in the ECP model is training cost. The cost factor addressed in the ECP model but not addressed in the LSC model is the cost of modification.

The second approach was to compare the life cycle cost estimates generated by the ECP model with the estimates generated by the LSC model. The precision of the estimates is of questionable value in this approach due to the treatment of different variables within the programs, and the fixed point flavor of the LSC model versus the time sensitive flavor of the ECP model. In order to make the estimates more compatible the training costs were subtracted from the LSC model, since the ECP model does not address training costs; and the cost of modification was subtracted from the ECP model, since the LSC model does not consider modification costs. The comparisons were made in an attempt to provide an evaluation of the ECP model's total cost estimating accuracy of some major cost driving variables. Certain cost elements will remain constant regardless of what configuration is decided upon, and the constant cost elements need not be addressed in the trade-off studies. For example, the cost of flying personnel in a single place aircraft would not change when purchasing increased reliability in a weapons system subsystem, nor would the cost of medical, dental, or security forces change to that system. Only the cost drivers involved in the decision need be addressed.

No attempt was made in this research to establish a hard and fast decision rule for measuring the estimates of the ECP model with the LSC model. The decision rule

must be made by the potential users based on their specific programs. As previously stated, the ECP model was designed to be used as a decision <u>aid</u> in making trade-offs between proposed engineering changes in relation to life cycle cost impacts. The ECP Model was never intended for programming and budgeting purposes, although some particular values computed by the model may be valid for use in econometric models.

CHAPTER IV

RESULTS, CONCLUSIONS AND RECOMMENDATIONS

Overview

This chapter contains the results, conclusions and recommendations of this research effort. The conclusions are divided into three parts, the first part is the treatment of the percentage of change in life cycle cost produced by the ECP model in comparison with the LSC model. The second part is the comparison of life cycle cost differences between the two models. The third part contains the overall conclusions, which are followed by the recommendations.

Percent of Change

In comparing the ECP model outputs to the outputs generated by the LSC model in relation to the magnitude of change produced by the two models, the difference appears minimal. Tables 2 through 9 reflect the dollar values generated by the two models. Table 10 displays the percent of change in first line unit level costs after adjustments for training and modification costs. As can be seen from the percent of change, both models agree within 4 percent. The greatest difference between the percent of change was produced by ECP 4 and ECP 8 resulting in a 3.3 percent

TABLE 2

COST GENERATED BY ECP 1*

	ECP Model	LSC Model
Not Implementing		
1. Spares	57,442	60,552
2. On-equipment	199	212
3. Off-equipment	35,091	35,181
4. Training	-	46
5. Management & Tech Data	-	75
Total Cost	92,733	96,036
Adjusted Cost	92,733	95,990
Implementing		
1. Spares	32,285	39,099
2. On-equipment	141	106
3. Off-equipment	24,149	22,780
4. Training	-	23
5. Management & Tech Data	-	37
6. Modification Cost	12,706	37
Total Cost	75,281	62,046
Adjusted Cost	62,575	62,023

*Costs may not add to totals due to rounding of costs to the nearest thousand dollar.

TABLE 3

COST GENERATED BY ECP 2*

	ECP Model	LSC Model
Not Implementing		
1. Spares	57,442	60,522
2. On-equipment	199	212
3. Off-equipment	35,092	35,181
4. Training	-	46
5. Management & Tech Data	-	75
Total Cost	92,733	96,036
Adjusted Cost	92,733	95,990
Implementing		
1. Spares	33,551	39,099
2. On-equipment	148	106
3. Off-equipment	25,476	22,780
4. Training	-	23
5. Management & Tech Data	-	37
6. Modification Cost	12,684	-
Total Cost	71,859	62,046
Adjusted Cost	59,175	62,023

*Costs may not add to totals due to rounding of costs to the nearest thousand dollar.

TABLE 4

COST GENERATED BY ECP 3*

	ECP Model	LSC Model
Not Implementing		
1. Spares	50,834	60,522
2. On-equipment	176	212
3. Off-equipment	31,094	35,181
4. Training	-	46
5. Management & Tech Data	-	75
Total Cost	82,104	96,036
Adjusted Cost	82,104	95,990
Implementing		
1. Spares	32,800	39,099
2. On-equipment	122	106
3. Off-equipment	20,866	22,780
4. Training	-	23
5. Management & Tech Data	-	37
6. Modification Cost	6,925	-
Total Cost	60,714	62,046
Adjusted Cost	53,789	62,023

*Costs may not add to totals due to rounding of costs to the nearest thousand dollar.

TABLE 5

COST GENERATED BY ECP 4*

	ECP Model	LSC Model
Not Implementing		
1. Spares	50,834	60,522
2. On-equipment	176	212
3. Off-equipment	31,094	35,181
4. Training	-	46
5. Management & Tech Data	-	75
Total Cost	82,104	96,036
Adjusted Cost	82,104	95,990
Implementing		
1. Spares	34,242	39,099
2. On-equipment	125	106
3. Off-equipment	21,377	22,780
4. Training	-	23
5. Management & Tech Data	-	37
6. Modification Cost	6,922	-
Total Cost	62,666	62,046
Adjusted Cost	55,516	62,023

*Costs may not add to totals due to rounding of costs to the nearest thousand dollar.

TABLE 6

COST GENERATED BY ECP 5*

	ECP Model	LSC Model
Not Implementing		
1. Spares	40,740	46,238
2. On-equipment	990	689
3. Off-equipment	59,664	60,412
4. Training	-	1,898
5. Management & Tech Data	-	138
Total Cost	101,394	109,374
Adjusted Cost	101,394	107,476
Implementing		
1. Spares	25,833	29,923
2. On-equipment	659	345
3. Off-equipment	38,900	37,206
4. Training	-	949
5. Management & Tech Data	-	69
6. Modification Cost	6,216	-
Total Cost	71,657	68,492
Adjusted Cost	65,444	67,543

*Costs may not add to totals due to rounding of costs to the nearest thousand dollar.

TABLE 7

COST GENERATED BY ECP 6*

	ECP Model	LSC Model
Not Implementing		
1. Spares	42,543	46,238
2. On-equipment	990	689
3. Off-equipment	59,319	60,412
4. Training	-	1,898
5. Management & Tech Data	-	138
Total Cost	102,852	109,374
Adjusted Cost	102,852	107,476
Implementing		
1. Spares	24,516	29,923
2. On-equipment	706	345
3. Off-equipment	41,635	37,206
4. Training	-	949
5. Management & Tech Data	-	69
6. Modification Cost	6,191	-
Total Cost	73,048	68,492
Adjusted Cost	66,857	67,543

*Costs may not add to totals due to rounding of costs to the nearest thousand dollar.

TABLE 8

COST GENERATED BY ECP 7*

	ECP Model	LSC Model
Not Implementing		
1. Spares	37,496	46,238
2. On-equipment	877	689
3. Off-equipment	52,561	60,412
4. Training	-	1,898
5. Management & Tech Data	-	138
Total Cost	90,934	109,374
Adjusted Cost	90,934	107,476
Implementing		
1. Spares	23,192	29,923
2. On-equipment	571	345
3. Off-equipment	33,476	37,206
4. Training	-	949
5. Management & Tech Data	-	69
6. Modification Cost	3,400	-
Total Cost	60,640	68,492
Adjusted Cost	57,240	67,543

*Costs may not add to totals due to rounding of costs to the nearest thousand dollar.

TABLE 9

COST GENERATED BY ECP 8*

	ECP Model	LSC Model
Not Implementing		
1. Spares	37,496	46,238
2. On-equipment	877	689
3. Off-equipment	52,561	60,412
4. Training	-	1,898
5. Management & Tech Data	-	138
Total Cost	90,934	109,374
Adjusted Cost	90,934	107,476
Implementing		
1. Spares	24,832	29,923
2. On-equipment	590	345
3. Off-equipment	34,692	37,206
4. Training	-	949
5. Management & Tech Data	-	69
6. Modification Cost	3,386	-
Total Cost	63,501	68,492
Adjusted Cost	60,115	67,543

*Costs may not add to totals due to rounding of costs to the nearest thousand dollar.

TABLE 10

PERCENT OF CHANGE BETWEEN THE BASELINE CONFIGURATION AND THE MODIFIED COST PREDICTED BY EACH MODEL

ECP Number	Percent of Change in the ECP Model	Percent of Change in the LSC Model
ECP 1	32.5	35.4
ECP 2	36.2	35.4
ECP 3	34.5	35.4
ECP 4	32.1	35.4
ECP 5	35.5	37.2
ECP 6	35.0	37.2
ECP 7	37.1	37.2
ECP 8	33.9	37.2

difference between the two models. The least difference was generated by ECP 7 resulting in a one-tenth of one percent difference.

The 3.3 percent of change in cost differences between ECP 4 and ECP 8 were attributable to the time sensitivity of the ECP model. Both ECPs simulated the incorporation of the modification on the 491st and subsequent production aircraft and required depot level modification of the 490 aircraft on hand. The time sensitivity of the ECP model resulted in costs that were associated with the quantity of systems on hand in each month. The

LSC model assumes that production is complete and all aircraft are on hand.

In the ECP model, the greater cost savings produced by ECP 4 and ECP 8 in relation to the other ECPs was attributed to a zero second destination shipping and handling cost of the retrofit kits which resulted from the depot level of compliance. The cost of depot level manpower was overshadowed by the cost savings associated with the distribution of kits. Bearing in mind that shipping costs are determined by weight, an item of different weight will generate different costs associated with shipping and handling.

Cost Differences

The second comparison of the computer model outputs was accomplished by comparing the adjusted cost differences associated with implementing the ECPs. This comparison was made between the models. Table 11 portrays the adjusted cost differences produced by the two models. The ECP model consistently produced lower cost differences than the LSC model. The range of the difference was 1.2 percent for ECP 2 to 22.8 percent for ECP 8. Again, ECP 4 and ECP 8 produce the greater differences.

Conclusions

The percent of change predicted within the ECP model for each of the eight ECPs in comparison to the baseline

TABLE 11

MODEL COST DIFFERENCES
(in thousands)

ECP Number	Dollar Value Change in the ECP Model	Dollar Value Change in the LSC Model	Model Cost Difference
ECP 1	30,158	33,967	3,809
ECP 2	33,558	33,967	409
ECP 3	28,315	33,967	5,654
ECP 4	26,588	33,967	7,379
ECP 5	35,950	39,933	3,983
ECP 6	35,995	39,933	3,938
ECP 7	33,694	39,933	6,239
ECP 8	30,819	39,933	9,114

was within 4 percent of the change produced by the LSC model. When evaluating the magnitude of change associated with an ECP on an aircraft weapon system, it can be inferred that the ECP model is at least as good as the LSC model. In the opinion of the researchers, the time sensitivity feature of the ECP model makes it a potentially more appropriate tool for evaluating ECPs incorporated during intermediate stages of production. In the ECP model, cost predictions can be projected monthly to display increasing logistics support cost as weapon system inventory increases.

The ECP cost differences between the LSC and ECP models vary between 1.2 and 11.2 percent for ECPs 1, 2, 5, and 6 which simulate a fixed inventory of on hand weapon systems. When employing the time sensitive feature of the ECP model via ECPs 3, 4, 7, and 8, which simulate weapon systems in production, the cost difference varies between 15.6 and 22.8 percent. This is a logical difference considering that the ECP model is not incurring maintenance costs on systems not yet delivered whereas the LSC model incurs costs for the maximum inventory thoughout the life cycle of the weapon system.

Cost estimates sensitive to MTBF can be realistically evaluated using the variable program factor option of the ECP Cost Evaluation model. Through this option, the failure relationship to item life can be investigated in terms of life cycle cost. Figure 3 represents the

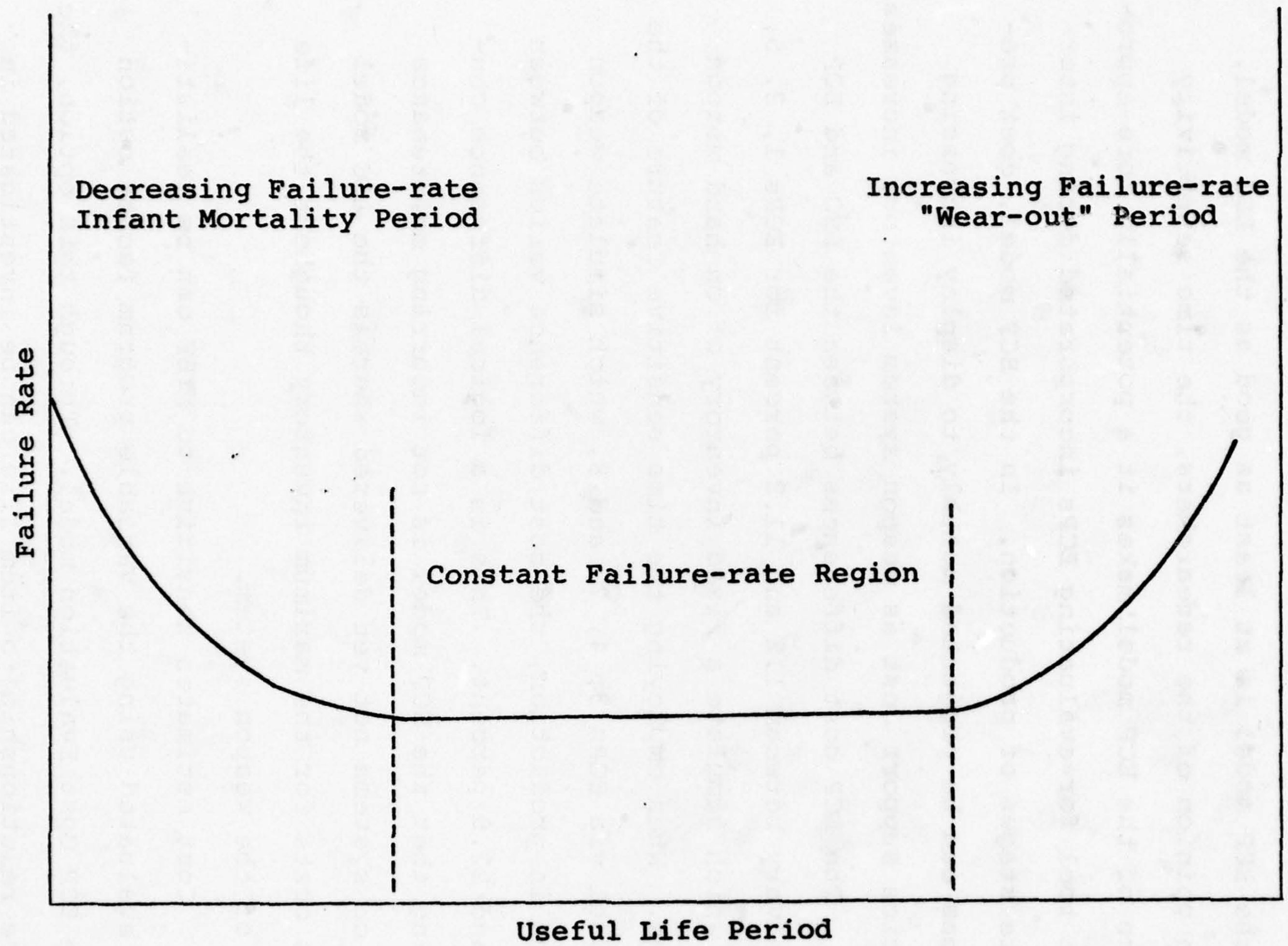

Fig. 3. Reliability Failure-rate Curve (31:1-6)

reliability failure-rate plotted against time. It is comcomly called the "bathtub curve" because of its shape (31:1-7). For a large sample, the curve will show three discrete periods of time (31:1-6).

The first period is the infant mortality period sometimes referred to as the burn-in period. This is when the item experiences a high initial failure rate due to manufacturing or personnel induced defects (31:1-6). The failure rate decrease to a level failure rate as the failed items are repaired or replaced. The level failure rate of the bathtub curve is known as the constant failure rate region (31:1-6). It is this region that the LSC model uses as a fixed MTBF in assessing life cycle costs. The third period is called the wear-out period and is accompanied by an exponential increasing failure rate (31:1-6).

In the ECP Cost Evaluation model the MTBMA can be adjusted with a variable program factor derived from the reliability failure-rate curve, thereby including both burn-in and wear-out periods in the cost evaluation. This capability to assess costs over a variable failure rate would permit the model user to make estimates with a greater degree of confidence.

An additional use of the variable program factor option could be to evaluate cost as a result of specific combat scenarios. In this situation, the user would adjust flying hours and attrition rates through the variable

program factor for the time periods he desires. He may also reduce flying hours to simulate fuel shortages or changes in manning policies. The use of the variable program factors for MTBMA, flying hours, and attrition rates allows for investigation of situations that are limited only by the user's imagination.

The sensitivity option of the model appears to be very valuable especially when considering that data elements from both contractor and government sources may be questionable estimates. The sensitivity study option provides for input of pessimistic, most likely, and optimistic estimates for up to forty-five variables listed in Appendix C that the user may need to investigate. By exercising this option of the model, the user is provided with a break-even month and cumulative annual costs for each estimate. The sensitivity of the forty-five variables can be ranked in order of their criticality, where critical variables are those variables that require only a small change in value to result in a large change in total cost. Those variables that could take on a wide range of values without producing significant cost differences can also be determined. It is important to know both critical and non-critical variables in the evaluation of ECPs in order to analyze the effects of proposed design changes on the total system and to know the most cost effective areas to invest time and money for design changes.

Recommendations

Model Enhancements

Additional options should be added to the computer program to provide particular cost totals that may be required by potential users. The researchers found it necessary to add print statements to the program in order to print out particular costs like total cost of spares, on-equipment and off-equipment maintenance costs and modification costs associated with the ECP. In the opinion of the researchers, options for increased output will not complicate or dilute the simplicity of the model.

Secondly, the addition of significant variables should be included in the model. These additions should include such variables as support equipment, publications, fuel, and software. These may or may not contribute to cost predictions, depending on the nature of the ECP, but the variables need to be addressed when they account for a significant change in cost.

Documentation of the model needs improvement. The documentation did not adequately explain the input variables; considerable research time was devoted to construction of variables and discussions with the model developer. A clear and concise users' handbook must be developed before the model is released to potential users.

A fourth recommendation for model enhancement is a long-range recommendation that impacts both the LSC and

ECP models. This recommendation stems from a quote attributed to Mr. M. Robert Seldon, Chief of Life Cycle Costing at General Dynamics Corporation:

> Plan LCC models carefully. The LCC model should be comprehensive but simple enough for trade studies. A possible solution to this apparent contradiction is to use one model for accounting purposes and a second, compatible model for trade study purposes [22:151-152].

The LSC model is scheduled for future revision to make it time sensitive (13). It may be advantageous to look at both the ECP and LSC model at the same time, making their variables and files compatible with each other. In short, make the ECP model a sister to the LSC model with the intent of using the LSC model for accounting purposes and the ECP model for tradeoff studies. This recommendation would require close scrutiny by personnel with a thorough understanding of both models.

Recommendations for Further Study

The researchers made minor changes to the model in order to break out particular cost elements required for comparison with the LSC model and in order to become familiar with the workings of the model. Potential users would require particular cost elements in a format easily understood. Further study should be directed to:

1. Provide more optional output formats.

2. Develop algorithms for the treatment of significant variables such as support equipment, software, fuel, etc.

3. Make a thorough evaluation of the sensitivity option of the model.

APPENDICES

APPENDIX A

ECP MODEL INPUT DATA FOR ECP 1

DATA REQUIRED	SOURCE	DERIVATION	INPUT
YEARS SYSTEM LIFE	LSC TEST FILE	PIUP*	10
MONTHS 1ST FY	LSC TEST FILE	PIUP	12
# A/C AT START	LSC TEST FILE	M * UEBASE	900
FLY HOUR/AC/MONTH STANDARD	LSC TEST FILE	$\frac{\text{TFFH}}{\text{PIUP*(12)*M*UEBASE}}$	25.46
ANY NEW A/C PRODUCTION	N/A	-	0
ATTRITION RATES:			
SYSTEM	N/A	-	0
OLD ITEM-RELATED CRASH	N/A	-	0
OLD ITEM-RELATED DAMAGE	N/A	-	0
# ITEMS/AIRCRAFT	LSC TEST FILE	QPA	1
INPUT FACTOR # FOR OLD ITEM MTBMA	LSC TEST FILE	UF	1 (Fly Hrs)

*LSC model variables are defined in Appendix B.

DATA REQUIRED	SOURCE	DERIVATION	INPUT
MTBMA IN FLYING HOURS	LSC TEST FILE	MTBF	300
PM AS A FRACTION OF:			
ON-EQUIP. MAINT.	SSC TEST FILE	$\frac{TFFH/SMI}{TFFH/MTBF + TFFH/SMI}$	.94
SAFETY MARGIN OLD SPARES	LSC TEST FILE	$\frac{(STK-DMDMEAN)}{DMDMEAN}$	.06
ORDER QTY OLD ITEM SPARES	LSC TEST FILE	TOTCOND/PIUP	11
ORDER MONTHS DELAY OLD ITEM SPARES	-	-	8
SERVICEABLE OLD SPARES AT START	LSC TEST FILE	DPIPE + STK/M	90
REPARABLE OLD SPARES AT START	-	LSC ASSUMPTION	0
UNIT PURCH COST OLD ITEM	LSC TEST FILE	UC	46200
UNIT PURCH COST NEW ITEM	ECP	1.3 * UC	60060
UNIT 1ST DEST SHIP COSTS OLD ITEM	LSC TEST FILE	PSC * W	13
UNIT 1ST DEST SHIP COSTS NEW ITEM	ECP FILE	PSC * W	13

DATA REQUIRED	SOURCE	DERIVATION	INPUT
UNIT 2ND DEST SHIP COSTS OLD ITEM	LSC TEST FILE	((1-OS) * PSC + OS * PSO) W	16.80
UNIT 2ND DEST SHIP COSTS NEW ITEM	ECP	((1-OS) * PSC + OS * PSO) W	16.80
LABOR RATES:			
PRODUCTION	-	-	15
DEPOT	LSC TEST FILE	DLR	12.44
BASE	LSC TEST FILE	BLR	11.70
M/H'S	LSC TEST FILE	SMH + MRO	10.08
MAT'L COST	LSC TEST FILE	-	-
INPUT FACTOR # FOR NEW ITEM MTBMA	ECP	-	1 (Fly Hrs)
MTBMA IN FLYING HOURS	ECP	-	600
PM AS A FRACTION OF:			
ON-EQUIP. MAINT.	LSC TEST FILE	$\frac{TFFH/SMI}{TFFH/MTBF + TFFH/SMI}$	.97
M/H'S	-	SMH + MRO	10.08

DATA REQUIRED	SOURCE	DERIVATION	INPUT
MAT'L COST	-	-	0
VARIABLE PROGRAM FACTOR FOR FLYING HOURS	N/A	-	0
VARIABLE PROGRAM FACTOR FOR ATTRITION RATES	N/A	-	0
VARIABLE PROGRAM FACTOR FOR OLD ITEM MTBMA	N/A	-	0
VARIABLE PROGRAM FACTOR FOR NEW ITEM MTBMA	N/A	-	0
INPUT FRACTION FOR 7 OLD ITEM MTBMA	LSC TEST FILE	-	-
ON-EQUIPMENT	-	RIP	.05
OFF-EQUIPMENT	-	1-RIP	.95
BASE REPAIR	-	RTS	.50
BASE CONDEMN.	-	BCOND	.05
BASE NRTS	-	NRTS	.45
DEPOT REPAIR	-	1 - DCOND	.80
DEPOT CONDEMN.	-	DCOND	.20
INPUT INTERVAL (DAYS) FOR 7 PARTS OLD ITEM MTBMA:	LSC TEST FILE	-	-

DATA REQUIRED	SOURCE	DERIVATION	INPUT
ON-EQUIPMENT	-	$\frac{PAMH + IMH + MRO}{24}$	1
OFF-EQUIPMENT	-	((1-OS)*DRCTC + OS*DRCTO) 30*NRTS + BRCT*(1-NRTS)*30	28
BASE REPAIR	-	BRCT * 30	4
BASE CONDEMN.	-	$\frac{PAMH + BBCMH + MRF}{24}$	1
BASE NRTS	-	$\frac{PAMH + BBCMH + MRF}{24}$	1
DEPOT REPAIR	-	30 (DRCTC * (1-OS) + OS * DRCTO)	57
DEPOT CONDEMN.	-	30 (DRCTC * (1-OS) * OS * DRCTO) - DMH/24	57
INPUT MANHOURS FOR 7 PARTS OLD ITEM MTBMA:	LSC TEST FILE	-	-
ON-EQUIPMENT	-	MRO + PAMH + IMH + RMH	3.08
OFF-EQUIPMENT	-	-	0
BASE REPAIR	-	MRF + BBCMH + BMH + TR + SR	4.15
BASE CONDEMN.	-	MRF + TR + SR + BBCMH	1.15
BASE NRTS	-	MRF + TR + SR + BBCMH	1.15
DEPOT REPAIR	-	DBCMH + DMH + TR + SR + MRF	3.35

DATA REQUIRED	SOURCE	DERIVATION	INPUT
DEPOT CONDEMN.	-	DBCMH + TR + SR + MRF	.85
INPUT MISC COSTS FOR 7 PARTS OLD ITEM MTBMA:	LSC TEST FILE	-	-
ON-EQUIPMENT	-	-	0
OFF-EQUIPMENT	-	-	0
BASE REPAIR	-	BMC * UC + BMH * BMR	4626.84
BASE CONDEMN.	-	-	0
BASE NRTS	-	-	0
DEPOT REPAIR	-	DMC * UC + DMH * BMR	4636.8
DEPOT CONDEMN.	-	-	0
INPUT FRACTION FOR 7 PARTS NEW ITEM MTBMA	SAME AS OLD ITEM	-	-
INPUT INTERVAL FOR 7 PARTS NEW ITEM MTBMA	SAME AS OLD ITEM	-	-
INPUT MANHOURS FOR 7 PARTS NEW ITEM MTBMA	SAME AS OLD ITEM	-	-
INPUT MISC COSTS FOR 7 PARTS NEW MTBMA	LSC TEST FILE	-	-
ON-EQUIPMENT	-	-	0

DATA REQUIRED	SOURCE	DERIVATION	INPUT
OFF-EQUIPMENT	-	-	0
BASE REPAIR	-	BMC * UC + BMH * BMR	6012.84
BASE CONDEMN.	-	-	0
BASE NRTS	-	-	0
DEPOT REPAIR	-	DMC * UC + DMH * DMR	6022.80
DEPOT CONDEMN.	-	-	0
COST OF EACH AIRCRAFT LOST	N/A	-	0
COST OF EACH AIRCRAFT DAMAGED	N/A	-	0
BASIS FOR MOD OF A/C	ECP	(ATTRITION AT FIELD LEVEL)	1
MONTH ATTRITION STRATEGY FOR O/H A/C STARTS	ECP	(BASED ON DELAY FOR NEW ITEM)	9
SAFETY MARGIN NEW SPARES	-	$\frac{(STK - DMDMEAN)}{DMDMEAN}$	0
ORDER QTY NEW ITEM SPARES	-	TOTCOND/PIUP	5
ORDER DELAY NEW ITEM SPARES	ECP	-	8
MISC COSTS TO MOD A/C ON-HAND	ECP	-	0
ADD. M/HOURS TO MOD A/C ON HAND	ECP	MRF + 2	2.24

DATA REQUIRED	SOURCE	DERIVATION	INPUT
% A/C ON-HAND MOD AT DEPOT	-	AFLC 173-10	.10
ORDER QTY RETROFIT KITS	ECP	UEBASE * M	900
MONTHS DELAY RETROFIT KITS	ECP	-	8
A/C RETROFIT KIT:			
UNIT PURCH	ECP	1.3 UC - UC	13860
1ST DEST SHIP COST	ECP	PSC * W	4
2ND DEST SHIP COST	ECP	((1-OS) * PSC + OS * PSC)W	5
ORDER QTY OLD ITEM SPARES MOD KIT	ECP	DPIPE + STK * M	90
MONTHS DELAY OLD ITEM SPARES MOD KIT	ECP	-	8
SPARES MOD KIT:			
UNIT PURCH	ECP	SAME AS RETROFIT KIT	13860
1ST DEST SHIP COSTS	ECP	SAME AS RETROFIT KIT	4
2ND DEST SHIP COSTS	ECP	SAME AS RETROFIT KIT	5
MISC COST TO MOD OLD SPARES	ECP	MRF + 2	2.24

DATA REQUIRED	SOURCE	DERIVATION	INPUT
ADD. M/HOURS TO MOD OLD SPARES	ECP	MRF + 2	2.24
% SPARES MOD AT DEPOT	ECP	-	.1
CHANGE ONE-TIME COST INPUT ARRAY	LSC TEST FILE	-	0

APPENDIX B

LSC MODEL VARIABLE DEFINITIONS

BBCMH - Average manhours to perform a shop bench check, screening, and fault verification on a removed FLU prior to initiating repair action or condemning the item.

BCOMD - Fraction of removed FLUs expected to result in condemnation at base level.

BLR - Base labor rate.

BMC - Average cost per failure for a FLU repaired at base level for stockage and repair of lower level assemblies expressed as a fraction of the FLU unit cost (UC). This is the implicit repair disposition cost for a FLU representing labor, material consumption, and stockage/replacement of lower indenture reparable components within the FLU (e.g., shop replaceable units or modules).

BMH - Average manhours to perform intermediate-level (base shop) maintenance on a removed FLU including fault isolation, repair, and verification.

BMR - Base consumable material consumption rate. Includes minor items of supply (nuts, washers, rags, cleaning fluid, etc.) which are consumed during repair of items.

BRCT - Average Base Repair Cycle Time in months. The elapsed time for a RTS item from removal of the failed item until it is returned to base serviceable stock (less time awaiting parts). For FLUs of the "black box" variety (e.g., avionics LRUs), the repair of which normally consists of removal and replacement of "plug-in" components (SRUs).

DBCMH - Same as BBCMH except refers to depot-level maintenance.

DCOND - Fraction of FLUs returned to the depot for repair (NRTS) expected to result in condemnation at depot level.

DLR - Depot labor rate.

DMC - Same as BMC except refers to depot repair actions.

DMDMEAN - Average monthly demand for the FLU.

DMH - Same as BMH except refers to depot-level maintenance.

DMR - Same as BMR except refers to depot level maintenance.

DPIPE - Number of FLU spares required to fill depot pipeline.

DRCT - Weighted average Depot Repair Cycle Time in months. The elapsed time for a NRTS item from removal of the failed item until it is returned to depot serviceable stock. This includes the time required for base-to-depot transportation and handling and the shop flow time within the specialized repair activity required to repair the item.

IMH - Average manhours to perform corrective maintenance of the FLU in place or on line without removal including fault isolation, repair, and verification.

K - Number of line items of peculiar shop support equipment used in repair of the FLU.

M - Number of intermediate repair locations (operating bases).

MRF - Average manhours per failure to complete off-equipment maintenance records.

MRO - Average manhours per failure to complete on-equipment maintenance records.

MTBF - Mean Time Between Failures in operating hours of the FLU in the operational environment.

NRTS - Fraction of removed FLUs expected to be returned to the depot for repair.

OS - Fraction of total force deployed to overseas locations.

PA - Number of new "p" coded reparable assemblies within the FLU.

PAMH - Average manhours expended in place on the installed system for Preparation and Access for the FLU; for example, jacking, unbuttoning, removal of other units and hookup of support equipment.

PIUP - Operational service life of the weapon system in years. (Program Inventory Usage Period)

PMB - Direct productive manhours per man per year at base level (includes "touch time," transportation time, and setup time).

PMD - Direct productive manhours per man per year at the depot (includes "touch time," transportation time, and setup time).

PP - Number of new "P" coded consumable items within the FLU.

PSC - Average packing and shipping cost to CONUS locations.

PSO - Average packing and shipping cost to overseas locations.

QPA - Quantity of like FLUs within the parent system. (Quantity per Application)

RIP - Fraction of FLU failures which can be repaired in place or on line without removal.

RMH - Average manhours to fault isolate, remove, and replace the FLU on the installed system and verify restoration of the system to operational status.

RTS - Fraction of removed FLUs expected to be repaired at base level.

SMH - Average manhours to perform a scheduled periodic or phased inspection on the system.

SMI - Flying hour interval between scheduled periodic or phased inspections on the system.

SP - Number of standard (already stock-numbered) parts within the FLU which will be managed for the first time at bases where this system is deployed.

SR - Average manhours per failure to complete supply transaction records.

STK - Number of FLUs required for base level stockage.

TFFH - Expected Total Force Flying Hours over the Program Inventory Usage Period.

TOTCOND - Number of FLU condemnations over the operational service life of the weapon system.

TR - Average manhours per failure to complete transportation transaction forms.

UC - Expected unit cost of the FLU at the time of initial provisioning.

UEBASE - The number of unit equivalent weapon systems per operating base.

UF - Ratio of operating hours to flying hours for the FLU. (Use Factor)

W - FLU unit weight in pounds.

1-DCOND - Fraction of FLUs returned to depot for repair that were not expected to be condemned at depot.

1-NRTS - Fraction of removed FLUs expected to be repaired at base level.

1-OS - Fraction of total force stationed in CONUS locations.

1-RIP - Fraction of FLU failures which must be removed for repair.

APPENDIX C

SENSITIVITY STUDY INPUTS

1. Number of aircraft on hand initial program month
2. Flying hours per aircraft per month (standard)
3. System aircraft attrition rate
4. Aircraft attrition due to old item
5. Aircraft damage rate due to old item
6. Number of items per aircraft
7. Operating hour/flying hour ratio old item
8. Sorties/aircraft/month
9. Landings/sortie
10. MTBMA old item
11. PM as a fraction of MTBMA old item
12. Manhours for PM per unit old item
13. Material and misc cost old item PM
14. MTBMA new item
15. PM as a fraction of MTBMA new item
16. Manhours for PM per unit new item
17. Material and misc cost old item PM
18. Safety margin old spares
19. Unit purchase cost old item
20. Unit purchase cost new item
21. First destination shipping cost old item
22. First destination shipping cost new item
23. Second destination shipping cost old item
24. Second destination shipping cost new item
25. Production labor rate
26. Depot labor rate
27. Base labor rate
28. Aircraft crash loss value
29. Aircraft damage loss value
30. Safety margin new spares
31. Material cost to incorporate modification into new production

32. Added manhours to incorporate modification into new production
33. Material cost to incorporate modification into aircraft on-hand
34. Added manhours to incorporate modification into aircraft on-hand
35. Percent aircraft modified at depot
36. Cost of retrofit kit
37. First destination shipping cost retrofit kit
38. Second destination shipping cost retrofit kit
39. Cost of old item spares mod kit
40. First destination shipping cost old item spares modification kit
41. Second destination shipping cost old item spares modification kit
42. Material cost to modify old item spares
43. Added manhours to modify old item spares
44. Percent old item spares modified at depot
45. Operating hour ratio new item

SELECTED BIBLIOGRAPHY

AD-A073 067 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OH SCHOOL--ETC F/G 5/1
EVALUATION OF THE ENGINEERING CHANGE PROPOSAL COST EVALUATION M--ETC(U)
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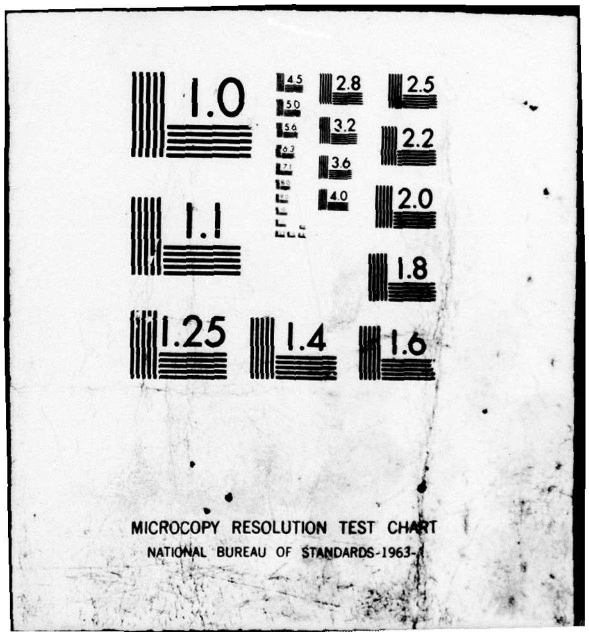
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

A. REFERENCES CITED

1. Ackoff, Russell L., and Maurice W. Sasieni. Fundamentals of Operations Research. New York: John Wiley & Sons, Inc., 1968.

2. Aeronautical Systems Division, Air Force Systems Command. Advanced Change Notice to Contract F33657-73-C-0500 with Fairchild Republic Company. Wright-Patterson AFB OH, 10 March 1978.

3. Air Force Acquisition Logistics Division, Air Force Logistics Command. Logistics Support Cost Model User's Handbook. Wright-Patterson AFB OH, January 1979.

4. Bennett, Captain Robert W., USAF, and Captain William D. Moravek, USAF. "A Cost Analysis of Procuring Improved Technical Order Data for the F-15 Weapon System." Unpublished master's thesis. LSSR 27-78A, AFIT/SL, Wright-Patterson AFB OH, June 1978. ADA 059571.

5. Cavender, Captain Raymond E., USAF. Application of the A-X 10-Year Operating and Support Cost Model to the F-4E. Wright-Patterson AFB OH, March 1971.

6. Douglas, Robert A. ECP/PIP Cost Evaluation Model. Unpublished research report, unnumbered. Directorate of Concepts and Analysis, Air Force Acquisition Logistics Division, Wright-Patterson AFB OH, 1977.

7. __________. Operations Research Analyst, Directorate of Concepts and Analysis, Air Force Acquisition Logistics Division, Wright-Patterson AFB OH. Personal interviews conducted from 8 February to 12 May 1979.

8. Fairchild Republic Company. A-10 Final Report Operation and Support (O&S) Cost Incentive Award Program. Fairchild Document LD160V0004. Farmingdale NY: 30 September 1977.

9. Fisher, Gene H. Cost Considerations in Systems Analysis. New York: American Elseiver Publishing Co., Inc., 1971.

10. Forrester, Jay W. Industrial Dynamics. Cambridge MA: The Massachusetts Institute of Technology Press, 1977.

11. Genet, Russell M. Chief, Plans and Analysis, Productivity, Reliability, Availability, and Maintainability (PRAM) Office, Air Force Acquisition Logistics Division, Wright-Patterson AFB OH. Telephone interview, 8 May 1979.

12. Glover, Captain William L., USAF, and Captain John O. Lenz, USAF. "A Cost Growth Model for Weapon System Development Programs." Unpublished master's thesis. SLSR 22-74B, AFIT/SL, Wright-Patterson AFB OH. August 1974. AD 785438.

13. Hall, Spain. Operations Branch Analyst, Directorate of Concepts and Analysis, Air Force Acquisition Logistics Division, Wright-Patterson AFB OH. Personal interviews conducted from 5 March to 12 May 1979.

14. Joint AFSC/AFLC Commanders' Working Group on Life Cycle Cost. Analysis of Available Life Cycle Cost Models and Their Application. Wright-Patterson AFB OH, June 1976.

15. ________. Life Cycle Cost Analysis Guide. Wright-Patterson AFB OH, November 1975.

16. ________. Review of the Application of Life Cycle Costing to the A-X/A-10 Program (1970-1973). Wright-Patterson AFB OH, October 1973.

17. ________. Understanding and Evaluating Life Cycle Cost Models. Wright-Patterson AFB OH, March 1977.

18. Poe, Lieutenant General Brice, USAF. "Getting Weapons that Do the Job," Air Force Policy Letter for Commanders. Washington: Government Printing Office, June 1977.

19. Rand Corporation. Getting "Real" Data for Life-Cycle Cost. Rand Paper Series P-5345, Santa Monica CA, January 1975.

20. Ropp, Richard F. Director of Plans and Analysis, HQ US Army Aviation Research and Development Command, DRDAV-BCE. Letter, subject: ECP/PIP Cost Evaluation Model, to AFALD/XRSP, 20 October 1977.

21. School of Systems and Logistics, Air Force Institute of Technology. Course QMT 353 Introduction to Life Cycle Costing. Wright-Patterson AFB OH, August 1977.

22. Seldon, M. Robert. Life Cycle Costing: A better Method of Government Procurement. Boulder CO: Westview Press, 1979.

23. Stewart, Perry C. "Evolution of Life Cycle Cost Application in the United States Air Force." Unpublished report, unnumbered, pages unnumbered, Office of the Deputy Chief of Staff for Acquisition Logistics, Headquarters, Air Force Logistics Command, Wright-Patterson AFB OH.

24. TIMS College on Simulation and Gaming Newsletter. Opinions on Validation/Verification. Providence RI, Winter 1979.

25. U.S. Department of the Air Force. Air Force Audit Agency. Integrated Logistics in Support of New Systems. (SRA 77278). Wright-Patterson AFB OH, 13 January 1978.

26. ________. Life Cycle Cost Management Program. AFR 800-11. Washington: Government Printing Office, 22 February 1978.

27. ________. Aircraft Maintenance Work Unit Code Manual USAF Series FB111A Aircraft. T.O. 1F111(B)A-06. Washington: Government Printing Office, 3 February 1976.

28. U.S. Department of Defense. Design to Cost. DOD 5000.28. Washington: Government Printing Office, May 1975.

29. ________. Life Cycle Costing Guide for System Acquisition. LCC-3. Washington: Government Printing Office, January 1973.

30. ________. Military Standard Configuration Control-Engineering Changes, Deviations and Waivers. MIL-STD-480. Washington: Government Printing Office, 30 October 1978.

31. U.S. Department of the Navy. Reliability Engineering Handbook. NAVAIR 01-1A-32. Washington: Government Printing Office, 1971.

32. U.S. General Accounting Office. Financial Status of Major Federal Acquisitions. (PSAD-78-60). Washington: Government Printing Office, 20 January 1978.

33. Wagner, Harvey M. Principles of Operations Research. Englewood Cliffs NJ: Prentice Hall, Inc., 1969.

B. RELATED SOURCES

Dover, Lawrence E., and Captain Billie E. Oswald, Jr., USAF. "A Summary and Analysis of Selected Life Cycle Costing Techniques and Models." Unpublished master's thesis. SLSR 18-74B, AFIT/SL, Wright-Patterson AFB OH, August, 1974. AD 787183.

Lowry, Major James H., USAF, Captain Martin F. Nahlen, USAF, and Captain William M. Peter, USAF. "Network Managed Air Force Projects: The Accuracy of Estimates as a Function of Time." Unpublished master's thesis. SLSR 1-75A, AFIT/SL, Wright-Patterson AFB OH, January 1975. AD A006326.

Rand Corporation. Life Cycle Analysis Procedures and Techniques: An Appraisal and Suggestions for Future Research. Rand Corporation Document P-6031. Santa Monica CA, October 1977.

BIOGRAPHICAL SKETCH OF THE AUTHORS

BIOGRAPHICAL SKETCH OF THE AUTHORS

Captain John W. Kehres enlisted in the United States Air Force on 22 July 1952. He has performed duty as an aircraft crewchief, periodic inspection dock chief, Inspection Branch Chief and Squadron Line Chief. He graduated from the University of Nebraska at Omaha and was commissioned via the Bootstrap Commissioning Program. After his commissioning he served as Flight Line Maintenance Officer and Maintenance Supervisor. He also served as F-16 Maintenance Project Officer at depot level. His assignment following graduation from AFIT is the Air Force Acquisition Logistics Division working in the F-16 System Program Office.

Captain Dan Kolpin is a graduate of Arizona State University where he majored in Aeronautical Technology. He received his commission through the university's ROTC program. He is an honor graduate of the Aircraft Maintenance Officers School and served his first tour at Tinker AFB as Chief of the Engine Division Time Compliance Technical Order (TCTO) section. He has served as Field Maintenance Officer, Flightline Officer, Job Control Officer and Deputy Scheduling Chief. Captain Kolpin's assignment after graduation from the Air Force Institute of Technology is to the International Logistic Center at Wright-Patterson Air Force Base, Ohio.